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Claims

1. A speed sensing system for measuring the speed of a target object, comprising:

5 a first speed sensor unit operatively disposed adjacent a surface of said target object, said first speed sensor unit configured to generate a first signal responsive to the passage of at least one random feature of said target object;

10 a second speed sensor unit operatively disposed adjacent a surface of said target object and displaced at a predetermined distance from said first speed sensor unit substantially in a direction of motion of the target object, said second speed sensor unit configured to generate a second signal responsive to the passage of said at least one random feature of said target object; and

15 a signal processor configured to receive said first and second signals, said signal processor further configured to apply a cross correlation analysis with a Fast Fourier Transform-based algorithm to determine a phase shift between said first and second generated signals, said phase shift inversely proportional to a speed of said target object.

20 2. The speed sensing system of Claim 1 further including:

a third speed sensor unit operatively disposed adjacent a surface of said target object, said third speed sensor unit configured to generate a third signal responsive to the passage of at least one feature of said target object;

25 a fourth speed sensor unit operatively disposed adjacent a surface of said target object and displaced at a predetermined distance from said third speed sensor unit substantially in a direction of motion of the target object, said fourth speed sensor unit configured to generate a fourth signal responsive to the passage of said at least one feature of said target object; and

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wherein said signal processor is further configured to receive said third and fourth signals, and to utilize said third and fourth signals to

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cancel signal components common to said first, second, third, and fourth signals.

3. The speed sensing system of Claim 2 wherein said signal processor is further configured to provide differential signals between the first and third signals, and between the second and fourth signals, and said signal processor is further configured to determine a phase shift between said third and fourth generated signals, said phase shift inversely proportional to a speed of said target object.

4. The speed sensing system of Claim 2 wherein said first and third speed sensing units define a first differential sensing pair;

wherein said second and fourth speed sensing units define a second differential sensing pair; and

wherein said first and second differential sensing pairs are spaced apart by a predetermined distance parallel to said direction of motion of the target object.

5. The speed sensing system of Claim 1 wherein said first and second speed sensing units are eddy current sensors; and

wherein said at least one feature is a random subsurface target feature.

6. The speed sensing system of Claim 1 wherein said first and second speed sensing units are optical sensors.

7. The speed sensing system of Claim 1 wherein said signal processor is configured to filter direct-current components from said first and second generated signals such that said generated signals have a zero signal mean.

8. The speed sensing system of Claim 1 wherein said signal processor is configured utilize a Fast Fourier Transform-based algorithm to determine a cross correlation function between said generated signals, said cross correlation function defined by:

$$y(\tau) = \int x_1(t + \tau) \cdot x_2(t) dt$$

where  $x_1$  is said first generated signal;

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$x_2$  is said second generated signal;

$t$  is a signal time; and

$\tau$  is a time delay between said generated signals.

- 5        9.        The speed sensing system of Claim 8 wherein said phase shift is associated with a maximum value for said cross correlation function; and wherein said signal processor is further configured to determine a maximum value for said cross correlation function; wherein a speed  $v$  of said target object is determined from:

$$v = \frac{L}{\tau_0}$$

- 10        where  $L$  is said predetermined distance; and  
 $\tau_0$  is a time delay corresponding to said determined maximum value for said cross correlation function.

- 15        10.        The speed sensing system of Claim 1 wherein said first speed sensor unit and said second speed sensor unit are disposed within a common housing.

11.        The speed sensing system of Claim 1 wherein said at least one target feature is a random surface feature of the target object.

12.        The speed sensing system of Claim 1 wherein said at least one target feature is a random subsurface feature of the target object.

- 20        13.        The speed sensing system of Claim 1 where each of said first and second speed sensing units has an identical sampling rate; and wherein said identical sampling rate is substantially greater than a signal variation rate for said first and second speed sensing units.

- 25        14.        A method for speed measurement of a target object, comprising the steps of:

observing at a first point, a passage of at least one random feature of the target object;

generating a first signal responsive to said passage of said at least one random feature at said first point;

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observing at a second point, displaced at a predetermined distance from said first point in a direction of motion of said target object, said passage of said at least one random feature of the target object;

5 generating a second signal responsive to said passage of said at least one random feature at said second point;

filtering direct-current components from said first and second generated signals;

10 applying a cross correlation analysis with a Fast Fourier Transform-based algorithm to calculate a phase shift between said filtered first signal and said filtered second signal, said phase shift inversely proportional to a speed of said target object.

15 15. The method of Claim 14 for speed measurement of an object wherein said phase shift is associated with a maximum value of a cross correlation function between said filtered first and second generated signals, and wherein said step of applying further includes calculating said maximum value of said cross correlation function between said filtered first and second generated signals, said cross correlation function defined by:

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$$y(\tau) = \int x_1(t + \tau) \cdot x_2(t) dt$$

where  $x_1$  is said first generated signal;

$x_2$  is said second generated signal;

$t$  is a signal time; and

$\tau$  is a time delay between said generated signals.

25 16. The method of Claim 15 for speed measurement of an object, further including the step of determining a speed  $v$  of said target object from:

$$v = \frac{L}{\tau_0}$$

where  $L$  is said predetermined distance;

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and  $\tau_0$  is a time delay corresponding to said determined maximum value for said cross correlation function.

17. The method of Claim 14 for speed measurement of an object further including the steps of :

5       observing at a third point, a passage of an additional feature of the target object;

          generating at least one additional signal responsive to said passage of said additional feature at said third point;

10       utilizing said at least one additional signal to cancel common elements present in each of said first and second generated signals.

18. A method of Claim 14 for speed measurement of a target object further including the step of:

          determining a relative position of the target object from said calculated phase shift.

15       19. The method of Claim 18 for determining a relative position of a target object wherein said determining step includes the step of integrating a calculated speed of said the target object with respect to time.